



Airport & Aircraft Safety R&D Notes

FAA's Airport & Aircraft Safety R&D Division

Oct.-Dec. 2002

Destructive Evaluation of Aging Small Airplanes

By 2010, the average age of the fleet of small airplanes (~180,000 aircraft) will approach 40 years. However, little is known about the consequences of the aging process on small airplanes. Comprehensive teardown inspections provide critical information to determine the condition of high-time operational aircraft. Data developed from teardown inspections can be used to provide guidance for maintaining structural and systems integrity. Limited teardown inspections of large civil aircraft have been performed, which resulted in a limited and proprietary knowledge base. There is no such knowledge base for small airplanes. Therefore, FAA research of

teardown investigations of small airplanes would provide an excellent opportunity to gain knowledge and insight required to support rule making, advisory circular preparation, and findings of compliance for small aircraft.

In September 2002, the FAA initiated a research project to evaluate two 20-year-old commuter airplanes, the first aircraft is shown in the figure below, a Cessna 402A. The state of the structure and mechanical and electrical systems will be evaluated using destructive and nondestructive techniques. The specific observations made of the two aircraft selected for teardown investigation will be documented and generalized as applicable to the small airplane fleet in operation today. The research is managed by the Materials and Structures Branch, AAR-450, at the FAA William J. Hughes Technical Center, and is sponsored by the FAA Small Airplane Directorate.



The Cessna 402A Aircraft

The research is being conducted primarily at the National Institute for Aviation Research Aging Aircraft Research Laboratory at Wichita State University. Several industry

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participants are assisting with many aspects of the project. Cessna is providing technical and engineering support and certified technicians to perform the supplemental inspections. Cessna's piston service center is providing service bulletins and service requirements applicable to the 402 aircraft.

CapeAir/Nantucket Airlines is providing the second aircraft, a 402C, and technicians to support the inspection and disassembly of the aircraft. Raytheon and Boeing are providing their expertise to evaluate the structures and wiring on commuter class aircraft. The FAA Airworthiness Assurance Nondestructive Inspection (NDI) Validation Center is participating in the program by monitoring the supplemental inspections and investigating advanced NDI methods that may be applicable to this type of commuter aircraft. The FAA Small Airplane Directorate and Wichita Aircraft Certification Office are assisting in the review of

service difficulty and accident and incident reports for the Cessna 402 aircraft along with certification requirements for these aircraft.

The short-term goals of this project are to provide insight into the condition of a typical aged small airplane and to determine the correlation between its maintenance history and current condition. The intent of this project is to document these findings for use in future investigations into the aged small airplane fleet and to determine if additional research is required to address specific problems observed during the teardown investigation. In the long term, the project will provide critical information to establish guidance and to ensure the required safety levels of continued airworthiness are provided by the current maintenance programs of small airplanes.

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Destructive Evaluation and Extended Fatigue Testing of Retired Aircraft Structure

In performing structural evaluations and assessments for continued airworthiness of high-time operational aircraft, comprehensive teardown inspections and extended fatigue testing have been and are conducted in the commercial and military sectors. Information and data gathered from such activities have helped ensure structural integrity of aircraft, especially those nearing their design service goal (DSG) and for evaluating airframe structures that are susceptible to widespread fatigue damage (WFD).

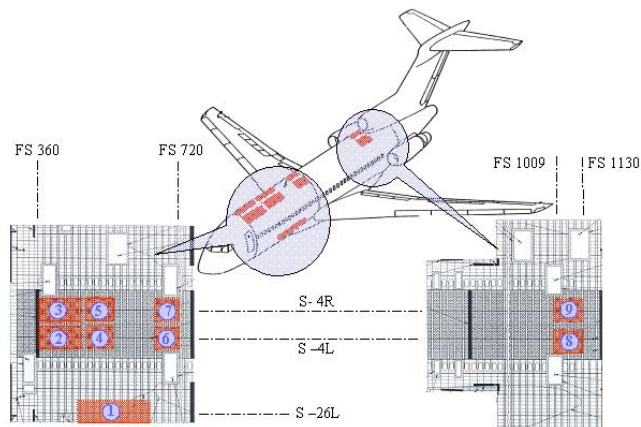
While the expertise and knowledge base needed to conduct teardown inspections are well established by the large commercial airframe original equipment manufacturers (OEM) and military sectors, comprehensive

guidelines and data that are documented and available to the broader aviation community are lacking. The destructive testing and analysis of structure removed from retired aircraft can provide the FAA with first-hand knowledge of teardown procedures that may be conducted in support of applications for continued airworthiness certification. Experience and knowledge gained from this destructive analysis will enable the FAA to issue essential rules, policy, and advisory circulars pertaining to the prevention of WFD.

The FAA and Delta Air Lines (DAL) have recently teamed to develop a knowledge base within the broader aviation community on the experimental procedures, analytical methods, and data reduction approaches for

a destructive evaluation and extended fatigue test of retired aircraft for use in developing and assessing programs to preclude WFD. This new 3-year project involves the destructive evaluation and extended fatigue test of a retired B-727 passenger aircraft near its DSG. The aircraft represents a typical Federal Aviation Regulation (FAR) Part 121 revenue-service passenger aircraft currently in the domestic fleet. The airplane was placed into service in 1974 and retired in 1998. During that time, the airplane accumulated 59,497 flight cycles and 66,434 flight hours. The airplane, owned and operated exclusively by DAL, was well maintained and stored and has a well-documented and accessible service history.

Sections representative of aircraft structure susceptible to WFD will be removed. At least nine sections from the fuselage lap joint area will be inspected, removed from the aircraft, shipped, and prepared for destructive evaluation and extended fatigue testing. The figure below shows the sections to be removed.



Locations of Sections to be Removed for Destructive Evaluation

The primary focus will be to characterize the state of multiple-site damage (MSD) using detailed NDI and destructive examination. NDI and visual inspection will be used to

catalog and fully document the condition of the selected areas for cracks, corrosion, and tear strap disbonds using OEM recommended standard practice and directed inspection requirements (service bulletins or airworthiness directives). Conventional and newer emerging NDI technologies will be assessed to determine their field capability to detect small cracks.

Using four panels, the state of MSD will be advanced through extended fatigue testing using the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) facility and then assessed through NDI and destructive evaluation. The FASTER fixture, shown in the figure below, is located and operated by the Materials and Structures Branch at the FAA William J. Hughes Technical Center and was established to assess the structural integrity of aircraft fuselage structure. Extended fatigue and residual strength testing of sections of actual fleet aircraft will provide data that will be used to validate structural response models. Those aircraft sections will also serve as a test bed to evaluate the sensitivity and effectiveness of standard and emerging inspection technologies.

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FASTER Fixture Components

Training of Federal Air Marshal Students on Aircraft Fire Safety Awareness

Over the past 25 years, Fire Safety Branch personnel have assisted in aircraft fire investigations around the world. In October 2002, Fire Safety Branch personnel in the Airport & Aircraft Safety R&D Division began training new Federal Air Marshals (FAMs) on the types of accidental aircraft cabin fires that might occur to better enable the FAMs to assist the aircraft crew during a fire emergency.

The FAM training consists of a lecture that is comprised of two primary sources: photographs of past aircraft fire accidents and incidents and fire test data that show how the conditions of the fire change from beginning to end. This data comes from numerous fire tests conducted by Fire Safety Branch personnel to develop improvements in aircraft fire safety.

The lectures begin by differentiating between in-flight and postcrash fires. Of greatest concern are in-flight fires originating in hidden areas that are often difficult to locate and extinguish. The goal is to extinguish or control the fire until the airplane can land at the nearest airport.

Past in-flight fires that have originated in lavatories or hidden cabin areas are also discussed. Particular emphasis is placed on the fatal Air Canada DC9 accident, which was caused by a fire originating in or near the rear lavatory. A video recreating the events and the actions taken by the crew is shown to illustrate the important lessons learned. The video shows the importance of clear and noncontradictory communication between the cabin and cockpit crew, immediate troubleshooting at the first occurrence of a problem (e.g., popped circuit breakers), identifying the source of a problem as quickly as possible, and activating hand-held extinguishers quickly.

Recent hidden in-flight fire incidents are presented with emphasis placed on the effectiveness of Halon 1211 hand-held extinguishers against hidden fires.

The lecture presents the development of requirements for Halon 1211 hand-held extinguishers. Halon 1211 discharged from hand-held extinguishers by crewmembers has successfully extinguished a number of hidden in-flight fires and very likely prevented a large loss of life on a number of occasions. For example, Halon 1211 extinguished a fire spreading into the cabin through the air return grill, likely saving the 231 occupants aboard a Delta flight from Hamburg to Atlanta. Because of its total flooding properties, Halon 1211 will reach a fire that is located anywhere within a relatively large space.

Postcrash fire, which are usually caused by the ignition of spilled jet fuel, occur as the result of impact with the ground, because of a hard or crash landing or an aborted takeoff. The goal is to improve postcrash fire survivability of aircraft occupants. Videos and data from past full-scale fire tests illustrate the characteristics of the cabin environment during a postcrash fire and the importance of cabin flashover on survival. When flashover occurs, the conditions within the cabin change from being highly survivable to highly nonsurvivable. The B-737 aborted take-off fire at Manchester in 1985 is perhaps the best-documented accident in regards to the fire characteristics and evacuation/survival. The aspects of this accident are described and accompanied with a video of a full-scale re-enactment test conducted by the Fire Safety Branch.

Rapid evacuation during a postcrash fire is critical to the survival of passengers. However, a key to rapid evacuation is the

assistance and assertive behavior of the cabin crew and FAMs. Some of the problems experienced in past accidents were hesitation at exits, identification of usable exits, passengers freezing in their seats, and competitive behavior that caused passengers to become wedged in narrow openings/pathways. A video of an evacuation test, which compares the behavior of assertive and nonassertive crew, shows that assertive behavior leads to an orderly, rapid emergency evacuation that can save lives in an accident.

The primary duty of the FAMs is to prevent aircraft hijackings. In addition to this duty, FAMs are available to assist crewmembers during serious incidents or accidents, including aircraft cabin fires. Thus, the availability of well-trained and physically fit FAMs is a great opportunity to enhance aircraft safety.

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Aging Electrical Systems

The FAA and the National Transportation Safety Board (NTSB) have reported hundreds of potentially hazardous incidents of smoke in aircraft cabins and cockpits. Such incidents are likely to increase with the aging of the in-service aircraft fleet. Because of recent aviation mishaps, investigators are focusing on the problems of aging aircraft wiring, specifically hard to detect arcing faults. The FAA, NTSB, and the Transportation Safety Board of Canada investigations cited electrical systems arcing as one likely cause of the cabin fire and crash of Swissair Flight 111 and the explosion and crash of TWA Flight 800. Similar, less catastrophic events have occurred in commercial transport and military aircraft fleets worldwide.

When the protective sheath of insulation on a wire cracks, tears, or is rubbed off by chaffing exposing the conductor, a short circuit or arc could occur. A short circuit occurs when electricity takes an unintended path. For example, condensation or other conductive material sometimes found on wire bundles can bridge the gap between an exposed wire conductor and an adjacent metal surface. If an electrical current follows the unintended path to the metallic

structure, a short circuit can cause overheating and possibly a fire. Power wiring in aircraft is protected by circuit breakers that detect continuous short circuits. Unlike a short circuit, electrical arcing is intermittent and occurs when high-current spikes cross an air gap between two conducting surfaces, emitting sparks that include molten material that is instantly vaporized in the high-energy discharge and produces extreme localized heat.

Currently, thermal circuit breakers in most aircraft are similar to those found in most household circuit breaker boxes. They are designed to protect the wiring from overheating associated with short circuit conditions. Circuit breakers generally do not protect against small sparks that can occur when aging, frayed wires become stressed to the point that arcing occurs between individual wires or between the wire harness and the aircraft structure.

To avoid the potential catastrophe that arcing could create, the FAA, in cooperation with the Naval Air Systems Command and industry, has developed a new form of circuit protection technology that is capable

of sensing an electrical arc along a wire and opening the circuit.

Arc-fault circuit interrupter technology will mitigate the consequence of wire failure without requiring the redesign of aircraft circuitry. It is a device that senses and responds to an electrical arc on a circuit as well as providing the circuit protection found in currently available circuit breakers. With FAA and Navy funding, two prototype alternating current, arc-fault circuit breakers have been developed and successfully flight-tested on the FAA's B-727 and a Navy C-9. The FAA, the Navy,

and aviation and electronic industries are working together to develop a common performance specification for the arc-fault circuit breaker. Some forms of this circuit breaker are now available for use in civilian and military aircraft. FAA and Navy researchers are now developing a miniaturized version that can easily be retrofitted into existing aircraft applications, as well as 28Vdc and 115V/3-phase arc-fault circuit breakers. The 28Vdc and 115V/3-phase arc-fault circuit breakers will be tested in fiscal year 2004.

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Metallic Materials Properties Development and Standardization: Continuation and Replacement of MIL-HDBK-5

The Metallic Materials and Elements for Aerospace Vehicle Structures handbook (MIL-HDBK-5) is recognized worldwide as the premier source of statistically based mechanical properties for metallic materials and joint allowables used in the design of aerospace vehicle structures. The handbook, which has been in existence for over 50 years, has been continuously reviewed and updated by industry and the government on a consensus basis. MIL-HDBK-5 has evolved significantly over the years. Its predecessor was first published in 1937 as Army-Navy-Commerce Handbook 5. The United States Air Force (USAF) took over the primary responsibility of continuing development in 1954 and, subsequently, the name of the book was changed to MIL-HDBK-5 in 1956. The MIL-HDBK-5 has been continuously developed to incorporate new methodologies, add new material properties, and update existing ones. This continuing effort has enabled the handbook to keep up with technology development and maintain up-to-date information for materials being used by industry.

Detailed guidelines for statistical analysis of data were incorporated into the handbook in 1971; these guidelines established standardized procedures for data requirements and analyses based on available statistical methods. The statistical procedures were further developed in 1984 to properly treat skewed data. As part of its continuing development, a major update of fracture toughness was completed in 1987. As digital information technology became available and easier to use, the handbook was distributed on CD-ROM in 1997.

For over 40 years, the USAF Materials and Manufacturing Directorate, at Wright-Patterson Air Force Base, OH, has been the lead government agency for this effort with ancillary support from the FAA and other Department of Defense agencies. However, after several years of budget reductions to the Air Force Science and Technology accounts and the move away from military specifications, alternative sources of funding were required to continue the MIL-HDBK-5 process.

In 2000, a plan was initiated to transition responsibilities and custodianship of the MIL-HDBK-5 from the USAF to the FAA. Because MIL-HDBK-5 is critical to commercial aircraft certification and continued airworthiness, the FAA committed to taking the lead for the federal government to continue the development and maintenance of the handbook. An Interagency Agreement was established in 2001, transitioning the primary responsibility from the USAF to the FAA to maintain the MIL-HDBK-5 process for establishing statistically based material allowables. During the transition, MIL-HDBK-5 will be replaced with the FAA document titled Metallic Material Properties Development and Standardization (MMPDS).

On April 22-25, 2002, the FAA William J. Hughes Technical Center hosted the First

MMPDS and 101st MIL-HDBK-5 Coordination Meetings. The Second MMPDS and 102nd MIL-HDBK-5 Coordination Meetings were held October 7-10, 2002, in Cocoa Beach, FL. Both meetings were well attended with over 50 participants.

In the last quarter of 2002, the FAA established a contract with Battelle Memorial Laboratory to develop and maintain the MMPDS. The new MMPDS document will be updated on a regular basis and ultimately replace MIL-HDBK-5 as the aviation industry standard for statistically based design properties of metallic materials. The final version of MIL-HDBK-5 is scheduled to be released in the second quarter of FY03, concurrently with the first edition of the MMPDS.

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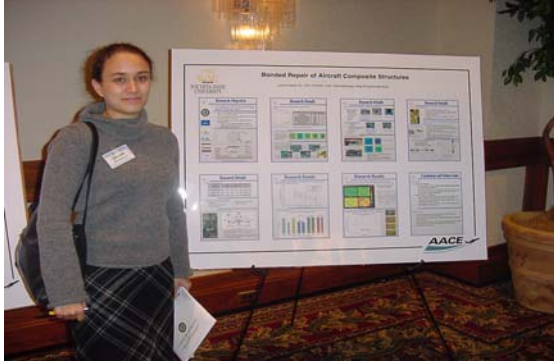
Second Annual Centers of Excellence Joint Meeting

The Second Annual Centers of Excellence (COE) Joint Meeting was held in Wichita, Kansas, on October 21-24, 2002. The meeting was jointly sponsored by the FAA, the National Institute of Aviation Research (NIAR) at Wichita State University, and four industry partners—the Boeing Company, Bombardier Aerospace, Cessna Aircraft, and Raytheon Aircraft. The intent of the meeting was to enhance Center operations by linking partners and providing an opportunity to foster new affiliations with potential sponsors.

The meeting opened with a Student Poster Session and parallel technical sessions on research from the Airworthiness Assurance Center of Excellence (AACE). Students from all the Centers submitted posters that were judged by representatives from the four industry sponsors. The four winners were:

- Lamia Salah for “Bonded Repair of Composite Airframe Structures”
- See-Cheuk Wong, See-Ho Wong, Dennis Regnier, Michael Boccia, Norma Campos, and Mushan Fong for “Effect of Critical Ice Shapes on Finite Wing Geometries”
- Juan Acosta for “Impact Damage Growth in Composite Sandwich Panels Under Cyclic Loading”
- Waruna Seneviratne for “Adhesive Characterization via Box Beam Lap Shear Torsion Test”

On Tuesday, representatives from industry, FAA, and academia participated on a panel session titled, “How Do We Maintain Aerospace Leadership Through Industry, Universities, and the FAA Working Together.”



Lamia Salah, Wichita State University, With her Winning Poster

Discussions on efforts to have the Centers themselves partner and work toward technology transfer gave Center members plenty to discuss during this session.

On Wednesday, the panel session titled, “The Next Five Years for the FAA Centers” gave each Center an opportunity to discuss their plans for the coming years. The COE for General Aviation (CGAR), the newest COE, was able to see where the other Centers have been and where their future paths might lead them.

Throughout the conference, academic partners provided in-depth technical reviews during open parallel breakout sessions. Speakers represented COE industry

affiliates, the FAA, members of the COE for Airport Technology (formerly Airport Pavement), the COE for Airworthiness Assurance (AACE), and the COE for General Aviation (CGAR). The meeting gave the Centers’ researchers a chance to engage both industry and sponsors.



Dr. Xiaogong Lee (right, in foreground), COE AACE Program Manager, Participates in a Tour of the Boeing Company Facility in Wichita, Kansas

In addition to the panel discussions and technical briefings, attendees also had the opportunity to tour either Boeing, Cessna, Raytheon, or NIAR.

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FAA-AANC NOTES

NDE of Carbon Composite Structures Via Quadrupole Resonance Spectroscopy

—Quadrupole Resonance (QR) has recently been shown to be a feasible method for the noncontact measurement of strain in polymeric fiberglass-reinforced composites. Due to the importance of carbon fiber-based composites for the aerospace industry and many other market sectors, the QR-approach is being adapted to this class of electrically conductive materials. Tiny crystals of a QR-active additive are embedded into the

composite or are applied as part of a surface coating. Strains in the composite are transferred to the additive crystals. These crystals can be interrogated via radio frequency pulses provided by a single-sided radio frequency coil. Thus, the additive crystals give rise to a strain-dependent QR frequency response. AANC personnel are assisting Quantum Magnetics, Inc. under a “work for others” agreement on a Small Business Innovative Research (SBIR) project to study the QR responses of carbon

composites coated with a resin/additive film under tensile loads. The QR sensor can be used to assess the structural integrity of composite structures anywhere on the structure and at any time during the lifetime of the structure. The method can aid in the

decision-making process regarding the continued use and the need for repair or replacement of composite components.

Dennis Roach, AANC, (505) 844-6078

Reports Corner

- Aircraft Age-Related Degradation Study on Single- and Three-Phase Circuit Breakers, DOT/FAA/AR-02/118, November 2002.
- Damage Tolerance Characterization of Sandwich Composites Using Response Surfaces, DOT/FAA/AR-02/101, November 2002.
- Development of a Component Head Injury Criteria (HIC) Tester for Aircraft Seat Certification—Phase I, DOT/FAA/AR-02/99, November 2002.
- Design, Manufacturing, and Performance of Stitched Stiffened Composite Panels With and Without Impact Damage, DOT/FAA/AR-02/111, October 2002.
- Evaluation of Conductivity Meters for Firefighting Foams, DOT/FAA/AR-02/115, October 2002.
- Impact Damage Characterization and Damage Tolerance of Composite Sandwich Airframe Structures – Phase II, DOT/FAA/AR-02/80, October 2002.
- Issues Concerning the Structural Coverage of Object-Oriented Software, DOT/FAA/AR-02/113, November 2002.
- Shear Stress-Strain Data for Structural Adhesives, DOT/FAA/AR-02/97, November 2002.
- Tabbing Guide for Composite Test Specimens, DOT/FAA/AR-02/106, October 2002.
- The Correlation of Heat Release Calorimetry Measurements, DOT/FAA/AR-TN02/104, November 2002.
- Design and Fabrication of a Head Injury Criteria-Compliant Bulkhead, DOT/FAA/AR-02/98, December 2002.
- Assessment of a Crack Tip Element-Based Approach for Predicting Delamination Growth in Interlayer-Toughened Composite Skin Stringer Panels, DOT/FAA/AR-02/102, December 2002.
- Parametric Study of Crashworthy Bulkhead Design, DOT/FAA/AR-02/103, December 2002.

- Fundamental Studies: Inspection Properties for Engine Titanium Alloys, DOT/FAA/AR-02/114, December 2002.
- Study of Commercial Off-The-Shelf (COTS) Real-Time Operating Systems (RTOS) in Aviation Applications, DOT/FAA/AR-02/118, December 2002.
- Mechanical Systems Characterization of Boeing 747 Aging Systems Test Bed Aircraft, DOT/FAA/AR-TN02/119, December 2002.
- Survey of Aviation Maintenance Technical Manuals Phase 3 Report: Final Report and Recommendations, DOT/FAA/AR-02/123, December 2002.

Personnel Notes

Tina DiIanni joins AAR-400 as part of the national Centers of Excellence program. She will be working as a Grants Program Analyst, assisting the program in budget and grants administration. DiIanni has an A.A.S. in Accounting from Atlantic Community College and has spent the previous 11 years with the budget branch at the FAA William J. Hughes Technical Center.

Upcoming Events

- The ATA Engineering, Maintenance and Material (EM&M) Forum, Integrated with the Aviation Week 2003 MRO Conference and Exhibition, April 15-17, 2003, Ft. Lauderdale, FL.
- 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference, April 2003, Norfolk, Virginia.
- 28th Conference and 22nd Symposium, International Committee on Aeronautic Fatigue, May 5-9, 2003, Lucerne, Switzerland.

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Airport and Aircraft Safety R&D Notes is published quarterly. If you have any questions about this issue, or have ideas for future issues, please contact the editor, Jason McGlynn via email at jason.mcglynn@faa.gov.